Student's Journal of Health Research Africa
Vol. 4 No. 6 (2023): June 2023 Issue
https://doi.org/10.51168/sjhrafrica.v4i6.551
Original article

A PROSPECTIVE STUDY ON SUSCEPTIBILITY-WEIGHTED IMAGING FOR DETECTION OF THROMBUS IN CEREBRAL VASCULATURE.

Dr Santosh Kumar Padhy[a], Dr Rajesh Pattanaik[a], Dr Ashis Kumar Satapathy[b,*]

[a] *Department of Radiodiagnosis, Institute of Medical Sciences and SUM Hospital, Siksha 'O' Anusandhan Deemed to be University.*
[b] *Department of Radiodiagnosis, Institute of Medical Sciences & SUM Hospital, Siksha 'O' Anusandhan Deemed to be University, Bhubaneswar.*

Abstract

Background & Objectives:

Cerebral vascular thrombosis can lead to devastating disability if not timely diagnosed and treated. Susceptibility-weighted imaging (SWI) is evolving as means of rapid investigation in the detection of intravascular clots in vascular thrombosis. This study aims to detect the diagnostic accuracy of SWI and its role in cerebral vascular thrombosis.

Materials & Methods:

The study was done on 40 patients, who underwent MR imaging of the brain using G Optima MR 360 1.5 Tesla MRI machine at the Department of Radiodiagnosis of IMS & SUM Hospital, Bhubaneswar. The data collected were categorized as arterial or venous infarcts, which were further evaluated based on the presence of intravascular clot, venous congestion, hemorrhagic areas, zone of penumbra and risk of hemorrhagic transformation on SWI with conventional MR sequences and NC-MRA/MRV.

Results:

In this study, SWI showed a sensitivity of 88.24% in the detection of intravascular thrombus as compared to 60.00% on combined T1W and T2W images with p value of 0.004. SWI has a sensitivity of 85.71% as compared to 72% on NC-MRA/MRV for intravascular clot detection with p value of 0.001. It could also detect the presence of hemorrhagic areas and cortical venous congestion with 100% sensitivity as compared to other sequences. In cerebral ischemic stroke, it could additionally detect the zone of penumbra and risk of hemorrhagic transformation which could not be detected on other sequences.

Conclusion:

SWI is considered a useful sequence that detects the presence of intravascular thrombus due to an increased concentration of deoxyhemoglobin. It also provides useful additional information regarding the presence of hemorrhagic areas and their risk of occurrence following thrombolytic therapy. Hence, SWI should be included in routine imaging protocol of the brain.

Keywords: SWI, GRE, MRI, acute infarct, stroke, CVST, cortical vein thrombosis, TOF, phase contrast, Submitted: 2023-06-24 Accepted: 2023-06-27

1. Introduction:

Susceptibility-weighted imaging (SWI) is a recent technique that exploits the magnetic properties of tissues, such as blood or iron content.1 It was earlier known as 'High-Resolution Blood oxygen level-dependent venography' because it provided increased visibility of the venous vasculature in the brain, including the minute vessels which were not seen on conventional MR sequences.2, 3, 4 As its potential was not limited to venography, it was renamed as 'Susceptibility Weighted Imaging'. In this sequence, the contrast mechanism between two tissues is the susceptibility differences between them. The specialty of this technique is to enhance the paramagnetic properties of substances.

Acute infarction, with or without haemorrhage, occurs due to thromboembolism, arterial stenosis, or other entity. In stroke protocol, along with conventional MR sequences, diffusion-weighted imaging (DWI), perfusion-weighted imaging (PWI), and MR angiography (MRA) has been incorporated.5 Vascular occlusion, which occurs either due to arterial stenosis, thromboembolism, or any other entity, can change the susceptibility by decreasing flow in the arterial circulation and increasing pooling of deoxygenated blood, thereby increasing the amount of deoxy-hemoglobin (Hb) that can be detected by SWI.

SWI is highly sensitive to the presence of haemorrhage, hence allows the visualization of microbleeds (MBs) which are not even visible on CT.6-8 Thromboembolism can change susceptibility by decreasing blood flow in the arterial circulation, and hence increases the amount of deoxy-Hb. It may additionally cause increased pooling of deoxygenated blood.3, 4

Cerebral venous sinus thrombosis (CVST) is difficult to diagnose clinically due to its variable presentation.9, 10 They present as non-specific lesions, including hemorrhage, edema, or infarction. Because of its sensitivity to susceptibility effects, SWI is of diagnostic value for intravascular clot detection in CVST along with other conventional MR sequences and MR Venogram (MRV).11 The hypointense engorged cortical vein with hyperintensity of the nearby brain tissue on SWI may suggest the presence of CVST with venous hypertension.

SWI can not only identify dural sinus thrombosis and cortical venous thrombosis, but it can also detect the extent of parenchymal hemorrhage that occurs after venous thrombosis, leading to infarction. It is also useful in differentiating chronic dural sinus thrombosis from hypoplastic dural sinuses.

This study emphasizes the diagnostic potential of SWI, in the case of cerebral arterial and venous thrombosis.

2. Methods:

2.1. Equipment Used:

G Optima MR 360 1.5 Tesla MRI machine.

2.2. Study Design:

Prospective study.

2.3. Study Location:

Institute of Medical Sciences and SUM Hospital, Bhubaneswar, Odisha, India

2.4. Sample Size:

40 patients.

2.5. Study Period:

2 years (July 2019 – June 2021)

2.6. Statistical Analysis:

- SPSS software version 19 will be used for statistical analysis.
- Data will be depicted in the form of tables and charts.
- Appropriate statistical tests like Paired T-test and other non-parametric tests will be used.

2.7. Sequences:

Axial T1WI, T2WI, TOF/PC, and SWI (SWAN).

* Corresponding author.
Email address: kumar.ashis89@gmail.com (Dr Ashis Kumar Satapathy)

2.8. Parameters Used:

Repetition time (TR)/TE, 49/40 ms
Flip angle 15°
Rectangular field of view (FOV , 7/8
Slice thickness- 2.2 mm
Images are acquired in the axial plane parallel to the bicommissural line.

2.9. Inclusion Criteria:

Patients who are referred to the Department of Radio Diagnosis, with a clinical history of headache, sudden loss of consciousness, or clinical suspicion of ischemic stroke leading to acute infarct with or without haemorrhage, and cerebral venous sinus thrombosis, are included in the study.

2.10. Exclusion Criteria:

- Patients in whom MRI is contraindicated
- Aneurysm clips.
- Any metallic fragment or foreign body.
- Cardiac pacemaker.
- Implanted Cardioverter-defibrillator.
- Cochlear implants.
- Known claustrophobia.
- Restless and uncooperative patients.

3. Results:

A total of 40 cases were included in the study. MRI brain was performed including conventional T1W, T2W, NC-MRA/MRV i.e. TOF/PC and SWI sequences.

3.1. Sex Distribution of Cases

Out of the 40 cases included in the study, 13 were female patients and 27 were male patients.

3.2. Age Distribution of Cases

3.3. Cerebral Vascular Thrombosis:

A total of 40 cases of cerebral vascular thrombosis, including arterial and venous sinus system, were identified as having evidence of restricted diffusion or other signal changes on conventional MR imaging and accordingly diagnosed as arterial and venous infarct.

SWI, T1W, and T2W images identified the presence of intravascular clots in 25, 17, and 16 cases of vascular thrombosis i.e. both arterial and venous thrombosis respectively. Out of these, the presence of intravascular clot was detected in only 12, 8, and 9 cases of arterial infarct and 13, 8, and 8 cases of venous infarct on SWI, T1W, and T2W images respectively. NC-MRA/MRV i.e. TOF and PC images could detect the presence of intravascular clots in 21 cases of vascular thrombosis. In arterial infarct, alone it could detect the presence of intravascular clot in 10 cases and 11 cases in venous infarct.

SWI could identify the presence of hemorrhagic areas in 21 cases whereas; T1W and T2W images could detect the presence of hemorrhagic areas in only 14 and 10 cases. SWI demonstrated prominent cortical veins in 28 cases i.e. in 70% of the cases. Thus suggesting the presence of increased deoxy-Hb in the draining veins. T1W and T2W sequences could not detect the presence of venous congestion in any case.SWI detected the presence of penumbra in 9 cases, which was obtained by comparing the area of prominent veins with the area of restricted diffusion. Thus, identifying potential subjects who may benefit from timely instituted thrombolytic therapy. Detection of penumbra was not applicable in cases of venous sinus thrombosis. The presence of penumbra could not be detected on T1W and T2W images.

SWI predicted the risk of hemorrhagic transformation prior to thrombolytic treatment in 13 cases by detecting the MBs, which are probably a risk factor for hemorrhagic transformation with thrombolytic therapy in acute ischemic stroke. This feature of vascular thrombosis was not applicable in cases of venous sinus thrombosis. T1W and T2W sequences could not predict the risk of haemorrhagic transformation in any case.

3.4. Features of vascular thrombosis on SWI and conventional MR sequences i.e. T1W and T2W images:

The presence of intravascular clot was detected in 62.5%, 40%, and 42.5% cases on SWI, T1W, and T2W images respectively i.e. including both ischemic infarct and CVST. In arterial thrombosis

Table 1: Age distribution of cases included in the study

AGE	FREQUENCY	PERCENT
30 AND BELOW	6	15
31 - 50	13	32.5
51 - 70	13	32.5
ABOVE 70	8	20
TOTAL	40	100

Table 2: Categorization of Brain Lesions Included In The Study:

LESION CATEGORY (INFARCTS)	NUMBER OF CASES	PERCENTAGE
ARTERIAL	26	65
VENOUS	14	35
TOTAL	40	100

Table 3: Features of vascular thrombosis on MR sequences included in study.

Sl No	Features of vascular thrombosis	T1W	T2W	SWI
1	Detection of intravascular clot (ICD)	16	17	25
2	Detection of hemorrhagic areas (DHA)	14	10	21
3	Presence of venous congestion (PVC)	0	0	28
4	Risk of hemorrhagic transformation (RHT)	0	0	13
5	Detection of penumbra (DP)	0	0	9

alone, SWI detected the presence of intravascular clot in 46.2% of cases, whereas T1W and T2W sequences could detect in only 30.8% and 34.6% of cases respectively.SWI detected the presence of intravascular clot in 92.9% of cases of CVST as compared to 57.1% of cases on T1W and T2W images. The presence of hemorrhagic areas on SWI was detected in 52.5% of cases including both arterial and venous infarct as compared to 35% of cases on T1W sequence and 25% of cases on T2W images.

Individually in arterial infarct, SWI detected the presence of hemorrhagic areas in 46.2% of cases whereas T1W and T2W sequences could detect in 26.9% and 11.5% of cases respectively. SWI detected the presence of hemorrhagic areas in 64.3% of cases of CVST as compared to 50% of cases on T1W and T2W images.

Features of venous congestion, risk of hemorrhagic transformation, and detection of penumbra could not be detected on T1W and T2W images, whereas they were detected on SWI in 70%, 50%, and 36.4% of cases respectively. In cases of arterial infarct on SWI, venous congestion was seen in 69.2% of cases. And it was seen in 71.4% of cases of CVST.

The risk of hemorrhagic transformation was detected in 50% of cases of arterial infarct on SWI. SWI could also detect the actual area of penumbra in 34.6% of cases of arterial infarct. The risk of hemorrhagic transformation and detection of penumbra did not apply to cases of CVST [Table 4].

Table 4 shows that SWI has a sensitivity of 87.50% and specificity of 54.17% for the detection of intravascular clots as compared to a sensitivity of 60.00% and specificity of 86.67% on T1W images. The p value was 0.008 which signifies that they are in statistically significant agreement.

Table 5 shows that SWI has a sensitivity of 75% for the detection of intravascular clots in arterial thrombosis as compared to the sensitivity of 50%

Table 4: Comparison of intravascular clot detection on SWI and T1SE sequences.

		SWI ICD PRESENT	ABSENT	TOTAL
T1W ICD	PRESENT	14	2	16
	ABSENT	11	13	24
	TOTAL	25	15	40

on T1W images. In CVST for clot detection, SWI has a sensitivity of 100% whereas T1W images have a sensitivity of 61.5%.

SWI has a sensitivity of 88.24% and specificity of 56.52% for the detection of intravascular clots as compared to a sensitivity of 60.00% and specificity of 86.67% on T2W images. The p-value was 0.004 which signifies that they are in significant agreement with each other. SWI has a sensitivity of 77.8% for the detection of clots in arte- rial thrombosis as compared to the sensitivity of 58.3% on T2W images. In CVST for clot detection, SWI has a sensitivity of 100% whereas T2W images have a sensitivity of 61.5%.

SWI could detect the presence of intravascular clots in 62.5% of cases, as compared to 42.5% of cases in both T1W and T2W combined together. Intravascular clot detection on SWI has a sensitivity of 88.24% for the detection of intravascular clots as compared to the sensitivity of 60.00% on combined T1W and T2W images. The p value was 0.004 which signifies that they are in significant agreement with each other. that SWI has a sensitivity of 77.8% for the detection of intravascular clots in arterial thrombosis as compared to the sensitivity of 58.3% on combined T1W and T2W sequences. In CVST for intravascular clot detection, SWI has a sensitivity of 100% whereas combined T1W and T2W sequences have a sensitivity of 61.5%.

Combined T1W and T2W have a sensitivity of 66.67% for the detection of hemorrhagic areas in cerebral vascular thrombosis i.e. including arterial and venous sinus systems. However, SWI shows a sensitivity of 100% for the detection of hemorrhagic areas. This is because SWI is sensitive to magnetic field inhomogeneity due to which it can detect very small bleeds within the infarct and make it more conspicuous than other conventional sequences [fig 1].

SWI has a specificity of 100% for the detection of venous congestion. Venous congestion could not be detected on conventional MR sequences. SWI has a specificity of 100% and an NPV of 65.4 for the detection of penumbra. The area of the penumbra could not be identified on conventional MR images.

3.5. Detection of cerebral vascular thrombosis on SWI and NC-MRA/MRV:

SWI detected the presence of intravascular clots in 62.5% of cases where as NC-MRA/MRV could detect intravascular clots in 52.5% of cases i.e. including both ischemic infarct and CVST. In arterial infarct alone SWI detected the presence of intravascular clot in 12 cases, whereas NC-MRA/MRV could detect in only 10 cases. In venous infarct, SWI detected the presence of intravascular clot in 13 cases as compared to 11 cases on NC-MRA/MRV sequence [Table 6].

SWI has a sensitivity of 85.71% and specificity of 63.16% for the detection of intravascular clots as compared to a sensitivity of 72% and specificity of 80% on NC-MRA/MRV images. The p value was 0.001 which signifies that they are in statistically significant agreement.

In arterial thrombosis SWI has a sensitivity of 80% for the detection of intravascular clots as compared to the sensitivity of 66.7% on NC-MRA/MRV images. In CVST for intravascular clot detection, SWI has a sensitivity of 90.9% whereas NC-MRA/MRV images have a sensitivity of 76.9%.

Student's Journal of Health Research Africa
Vol. 4 No. 6 (2023): June 2023 Issue
https://doi.org/10.51168/sjhrafrica.v4i6.551
Original article

Table 5: Cross-tabulation of intravascular clot detection in ischemic stroke and CVST on SWI and T1W sequences.

			SWI ICD PRESENT	ABSENT	TOTAL
ARTERIAL INFARCT	T1W ICD	PRESENT	6	2	8
		ABSENT	6	12	18
		TOTAL	12	14	26
CVST	T1W ICD	PRESENT	8	0	8
		ABSENT	5	1	6
		TOTAL	13	1	14

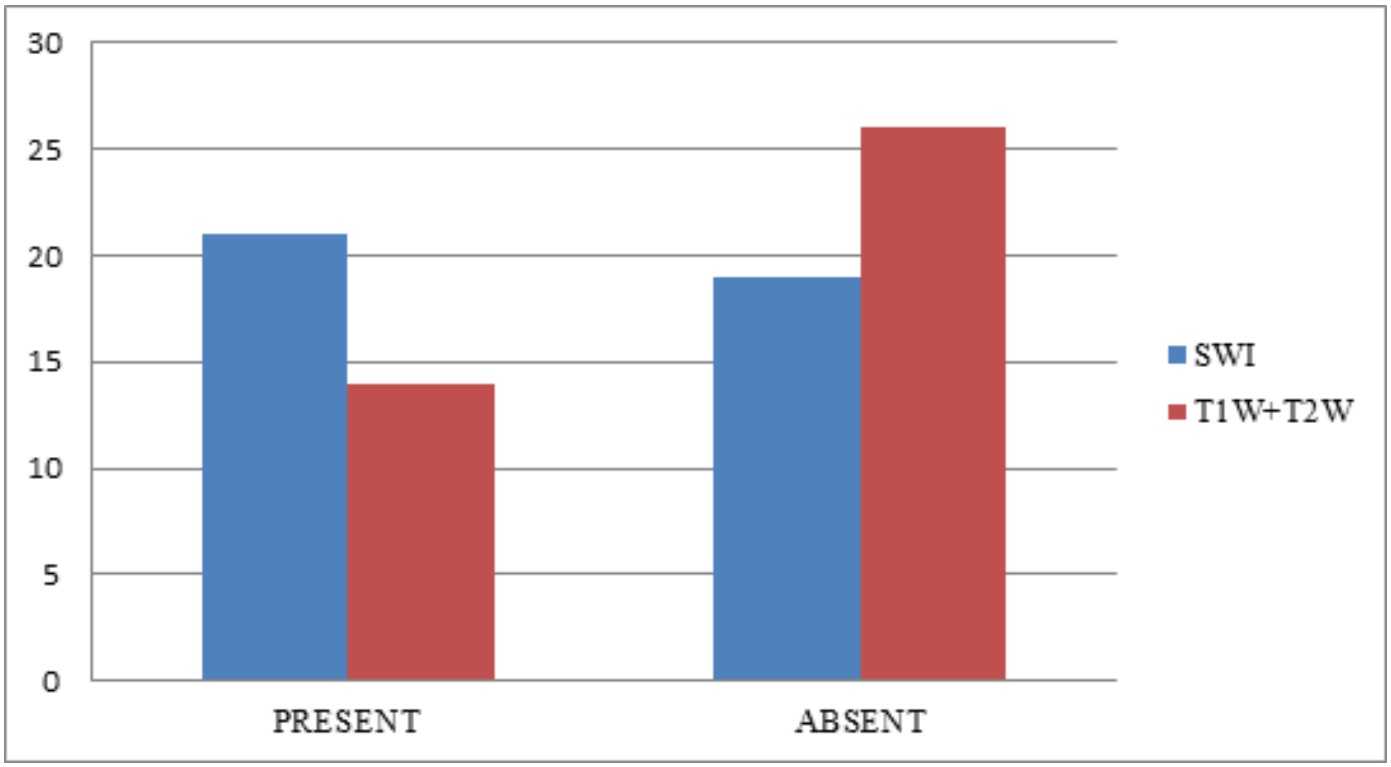

Figure 1: Bar chart on comparison of detection of hemorrhagicareas on SWI and combined T1W and T2W sequences.

Table 6: Comparison of intravascular clot detection on SWI and NC MRA/MRV sequences.

		SWI ICD PRESENT	ABSENT	TOTAL
NC-MRA/MRV	PRESENT	18	3	21
	ABSENT	7	12	19
	TOTAL	25	15	40

4. Discussion:

In this study, there were a total of 40 cases out of which 26 were cases of cerebral infract and 14 were CVST and a comparative assessment was made between diagnostic information provided by conventional sequences like T1W, T2W, NC-MRA/MRV, and SWI.

These sequences were compared based on direct (detection of intravascular clot in the arterial circulation and dural venous sinuses) and indirect (haemorrhagic areas, presence of venous congestion, detection of penumbra, and risk of haemorrhagic transformation) evidence of cerebrovascular thrombosis. A category-wise description of the results obtained in this study is mentioned below.

SWI plays an important role in the imaging of arterial infarct and CVST patients. Several characteristics of acute infarcts and CVST were dealt with in the present study of 26 cases of stroke and 14 cases of CVST.

We encountered the presence of intravascular clot in 62.5%, 40%, and 42.5% cases on SWI, T1W, and T2W images respectively i.e. including both ischemic infarct and CVST. In cases of arterial thrombosis, SWI detected the presence of intravascular clot in 46.2% of cases, whereas T1W and T2W sequences could detect in only 30.8% and 34.6% of cases respectively. In cases of CVST, SWI detected the presence of intravascular clot in 92.9% of cases of CVST as compared to 57.1% of cases in both T1W and T2W images.

T1W and T2W sequences combined could detect the presence of intravascular clots in 42.5% of cases. Intravascular clot detection on SWI has a sensitivity of 88.24% as compared to the sensitivity of 60.00% on combined T1W and T2W images. The p value is 0.004 which signifies that they show a statistically significant association. Therefore, SWI is more accurate than conventional MR sequences in the detection of intravascular clots.

This is in agreement with the results obtained by Lingegowda et al and Flacke S et al. They individually concluded that the susceptibility sign on SWI is more sensitive in detecting the acute thrombus as compared to hyperdense artery sign on CT and hyperintense artery sign on conventional MR sequence.12 In CVST cases, the results in our study are statistically in agreement with the study conducted by Idbaih et al who reported higher accuracy in detection of intravascular clots on SWI.11

In arterial circulation, SWI has a sensitivity of 77.8% for the detection of intravascular clots as compared to the sensitivity of 58.3% on combined T1W and T2W sequences. The p value was 0.018 which signifies that they are in statistically significant association. In CVST for intravascular clot detection, SWI has a sensitivity of 100% whereas combined T1W and T2W sequences have a sensitivity of 61.5%. Therefore, SWI is a more sensitive tool to detect the presence of intravascular clots in venous sinuses than arterial circulation.

In 2 cases of arterial infarct, the presence of intravascular clot in the petrous part of ICA could not be detected on SWI because of air-bone interface artifact. In another 2 cases of CVST, the presence of intravascular clot in venous sinuses could be partially detected on the T1W sequence, whereas the complete extent of intravascular clot is demonstrated on SWI.

In 8 out of 40 cases, we found hyperintense signals on conventional MR sequences in the transverse and sigmoid sinuses of one side. However, there was no evidence of thrombosis on SWI. This could be due to a hypoplastic sinus or the presence of slow flow within the sinus. This feature is not considered in the statistical analysis of this study.

NC-MRA/MRV demonstrated the presence of clot in 52.5% of cases as compared to 62.5% of cases by SWI. SWI has a sensitivity of 85.71% and specificity of 63.16% for the detection of intravascular clots as compared to the sensitivity of 72% and specificity of 80% on NC-MRA/MRV sequence. The p value is 0.001 which represented that, they are in statistically significant agreement.

In arterial thrombosis, SWI showed a sensitivity of 80% for the detection of intravascular clots as compared to the sensitivity of 66.7% on NC-MRA/MRV images. In CVST for intravascular clot detection, SWI showed a sensitivity of 90.9% whereas NC-MRA/MRV sequence has a sensitiv-

ity of 76.9%.

It is not expected that SWI will replace NC-MRA/MRV in the management of patients diagnosed as a case of cerebrovascular thrombosis because NC-MRA/MRV provides important additional information for stroke identification and classification due to peripheral vessel rarefication.13 Rather, both techniques would complement each other for visual identification of the occluded vessel.

We detected the presence of hemorrhagic areas on SWI in 52.5% of the cases as compared to T1W and T2W sequences, which identified it in 35% and 25% of cases respectively. For the detection of hemorrhagic areas in cerebral vascular thrombosis i.e. including arterial and venous sinus systems combined T1W and T2W have a sensitivity of 66.67%. However, SWI shows a sensitivity of 100% for the detection of hemorrhagic areas. This is because SWI is sensitive to magnetic field inhomogeneity. Hence, it can detect the presence of MBs within the infarct and make it more conspicuous than other conventional sequences. SWI thus proved to be superior in the detection of hemorrhagic areas. This is comparable to previous studies, which have done similar comparisons in cases of cerebrovascular thrombosis.14-16

SWI detected the presence of venous congestion in 70% of all cases of arterial and venous infarct with 100% sensitivity. This feature could not be detected on conventional MR sequences. This is in agreement with studies 17, 18. They concluded that decreased cerebral perfusion stimulated various compensatory mechanisms which increased tissue OEF causing an increase in deoxy-Hb in venous channels draining that region. This elevated deoxy-Hb to oxy-Hb ratio leads to the presence of prominent cortical veins over the affected cerebral hemisphere on SWI.

Hence, by demonstrating the presence of venous congestion or prominence of cortical veins and hemorrhagic areas in SWI, it alerts the radiologist to include vascular thrombosis as a probable cause in cases where conventional MR sequences are unremarkable.

In our study, by combining DWI and SWI images we predicted the zone of penumbra which is a mismatch of diffusion with area of perfusion. The area of perfusion was identified by the presence of prominent cortical veins on SWI. We detected penumbra in 34.6% of the cases. Therefore, without the use of a contrast agent, SWI can demonstrate the additional benefit of predicting the extent of impaired perfusion and future area of stroke.

In this study, we have considered the presence of MBs on SWI as a probable risk factor for hemorrhagic transformation in cases that may receive thrombolytic therapy. We encountered the presence of MBs in 50% of the cases. This finding is in agreement with other studies. Therefore, the presence of MBs on SWI may prove to be a risk factor of post thrombolytic hemorrhagic transformation.19,20

In a separate study by Hermier M et al, it is stated that a prominent transcerebral vein may be considered a risk factor for hemorrhagic transformation in post thrombolytic cases.16 However, in our study we have only considered the presence of MBs as a probable cause of hemorrhagic transformation.16

A study where stated that thrombolytic treatment can be used safely if patients have a small number of MBs. And the risk factor for hemorrhagic transformation would increase if there were a large number of MBs.21 Hence, SWI can be used as an effective tool in the planning of the treatment protocol.

5. Limitation:

The limitations of this study depend on the specific MRI parameters used in our center that may influence the results and also on the expertise of the center in diagnosing arterial and venous thrombosis.

6. Conclusion:

SWI is a recent technique that provides a unique contrast and new possibilities, especially in the neuroimaging of cerebral thrombosis. SWI is a highly sensitive sequence as compared to other conventional MR sequences and NC-MRA/MRV for the detection of vascular thrombosis or clot.

SWI along with DWI may detect the possible zone of the penumbra. Hence, it can guide the management of cases without undergoing a perfusion study and can also reduce the cost of the investigation. It can be effectively used as a tool to predict the risk of post thrombolysis haemorrhagic transformation in acute arterial infarct by identifying the microbleeds. SWI is the only sequence that precisely detects the presence of intravascular clot, cortical venous congestion, zone of penumbra, and risk of haemorrhagic transformation. Hence, it overcomes all the limitations of conventional MR sequences. SWI has an important diagnostic value in addition to conventional MRI and NC-MRA/MRV in cases of cerebral vascular thrombosis and helps to guide timely management and predict complications.

7. Acknowledgment:

None

8. List of abbreviations:

SWI- Susceptibility weighted imaging
DWI- Diffusion-weighted imaging
PWI- Perfusion-weighted imaging
MRA- MR angiography
MB- Microbleed
CVST- Cerebral venous sinus thrombosis
MRV- MR Venogram

9. Publisher details:

Publisher: Student's Journal of Health Research (SJHR)
(ISSN 2709-9997) Online
Category: Non-Governmental & Non-profit Organization
Email: studentsjournal2020@gmail.com
WhatsApp: +256775434261
Location: Wisdom Centre, P.O.BOX. 148, Uganda, East Africa.

10. References:

1. Haacke EM, Mittal S, Wu Z, Neelavalli J, Cheng YC. Susceptibility weighted imaging: Technical aspects and clinical applications, Part 1. AJNR Am J Neuroradiol 2009;30:19-30.
2. Tsui YK, Tsai FY, Hasso AN, Greensite F, Nguyen BV. Susceptibility weighted imaging for differential diagnosis of cerebral vascular pathology: A pictorial review. J Neurol Sci 2009;287:7-16.
3. Santhosh K, Kesavadas C, Thomas B, Gupta AK, Thamburaj K, Kapilamoorthy TR. Susceptibility weighted imaging: A new tool in magnetic resonance imaging of stroke. Clin Radiol 2009;64:74-83.
4. Lee BC, Vo KD, Kido DK, Mukherjee P, Reichenbach J, Lin W, et al. MR high-resolution blood oxygenation level dependent venography of occult (low-flow) vascular lesions. AJNR Am J Neuroradiol 1999;20:1239–42.
5. Schellinger PD, Jansen O, Fiebach JB, et al. A standardized MRI stroke protocol: comparison with CT in hyperacute intracerebral hemorrhage. Stroke 1999;30:765–68.
6. Hermier M, Nighoghossian N. Contribution of susceptibility-weighted imaging to acute

stroke assessment. Stroke 2004;35:1989–94.
7. Sehgal V, Delproposto Z, Haacke EM, et al. Clinical applications of neuroimaging with susceptibility-weighted imaging. J Magn Reson Imaging 2005;22: 439–50.
8. Thomas B, Somasundaram S, Thamburaj K, et al. Clinical applications of susceptibility weighted MR imaging of the brain: a pictorial review. Neuroradiology 2008;50:105–16.
9. Bousser MG, Chiras J, Bories J, Castaigne P. Cerebral venous thrombosis—a review of 38 cases. Stroke 1985;16:199–213.
10. Ameri A, Bousser MG. Cerebral venous thrombosis. Neurol Clin 1992;10:87–111.
11. Idbaih A, Boukobza M, Crassard I, Porcher R, Bousser MG, Chabriat H. MRI of clot in cerebral venous thrombosis: high diagnostic value of susceptibility-weighted images. Stroke 2006;37:991–5.
12. Reichenbach JR, Venkatesan R, Schillinger DJ, Kido DK, Haacke EM. Small vessels in the human brain: MR venography with deoxyhemoglobin as an intrinsic contrast agent. Radiology 1997;204:272-7.
13. Haacke EM, Dmitriy SL, Yablonskiy A. In vivo validation of the bold mechanism: a review of signal changes in gradient echo functional MRI in the presence of flow. Int J Imaging Systems Technology 1995;6:153–63.
14. Haacke EM, Xu Y, Cheng YC, Reichenbach JR. Susceptibility-weighted imaging(SWI). Magn Reson Med 2004;52:612-8.
15. Chalela JA, Kidwell CS, Nentwich LM, Luby M, Butman JA, Demchuk AM, et al. Magnetic resonance imaging and computed tomography in emergency assessment of patients with suspected acute stroke: a prospective comparison. Lancet 2007;369:293-8.
16. Hermier M, Nighoghossian N, Derex L, Adeleine P, Wiart M, Berthezene Y, et al. Hypointense transcerebral veins at T2*-weighted MRI: a marker of hemorrhagic transformation risk in patients treated by intravenous tissue plasminogen activator. J Cereb Blood Flow Metab 2003;23:1362-70.
17. Baron JC, Bousser MG, Rey A, Guil- lard A, Comar D, Castaigne P. Reversal of focal "misery-perfusion syndrome" by extra-intracranial arterial bypass in hemodynamic cerebral ischemia: a case study with 15O positron emission tomography. Stroke 1981;12:454-9.
18. Gordon AL, Goode S, D'Souza O, Auer DP, Munshi SK. Cerebral misery perfusion diagnosed using hypercapnic blood-oxygenation-leveldependent contrast functional magnetic resonance imaging: a case report. Journal of Medical Case Reports 2010;4:54-9.
19. Kesavadas C, Santhosh K, Thomas B. Susceptibility weighted imaging in cerebral hypoperfusion - can we predict increased oxygen extraction fraction? Neuroradiology 2010.
20. Tamura H, Hatazawa J, Toyoshima H, Shimosegawa E, Okudera T. Detection of Deoxygenation-Related Signal Change in Acute Ischemic Stroke Patients by T2*-Weighted Magnetic Resonance Imaging. Stroke 2002;33:967-71.
21. Leach JL, Fortuna RB, Jones BV, et al. Imaging of cerebral venous thrombosis: current techniques, spectrum of findings, and diagnostic pitfalls. Radiographics 2006;26 Suppl 1:S19–41.

Author biography

Dr Santosh Kumar Padhy Assistant Professor, Department of Radiodiagnosis, Institute of Medical Sciences and SUM Hospital, Siksha 'O' Anusandhan Deemed to be University.

Dr Rajesh Pattanaik Assistant Professor, Department of Radiodiagnosis, Institute of Medical Sciences and SUM Hospital, Siksha 'O' Anusandhan Deemed to be University.

Dr Ashis Kumar Satapathy Assistant Professor, Department of Radiodiagnosis, Institute of Medical Sciences & SUM Hospital, Siksha 'O' Anusandhan Deemed to be University, Bhubaneswar.